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The development trajectories of wind power and solar PV power in China: A comparison and policy recommendations

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ABSTRACT

Wind power and solar PV power are the two major renewable energy technologies that are currently under rapid development in China. In this paper, the similarities and differences between the development trajectories of the two sectors are examined in terms of development status, development policy and development trend. Five interesting findings from the comparison are obtained and several policy recommendations are made. This paper contributes to the study on China's renewable energy policy from a new perspective.

Contents

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1. Introduction

Wind power and solar PV power are the two major renewable energy technologies that have received much attention from many governments around the world including China and are currently under rapid development. China is abundant in both wind resources and solar resources. According to the China Meteorological Administration, onshore wind power resources at an altitude of 10 m total about 3226 GW in terms of electricity, among which 253 GW is available for development and utilization. At an altitude of 50 m, the resources available for development and utilization double to more than 500 GW [2]. Offshore wind power resources in coastal waters aggregate to 750 GW [1]. China is also rich in solar resources with daily average radiation of 4 kW h/m^2 day. More than two-thirds of the country's area can receive a radiation of more than 5000 MJ/m yr and more than 2200 h of sunshine. In addition to similarity in abundance, the two resources are very much similar in distribution, being unevenly distributed and far from the eastern power load areas of the country (Figs. 1, 2) [2,3].

Though similar in resource abundance and distribution, priority has been given to the expansion of wind power in China. As a consequence, wind power has greatly outgrown PV power in the country. China has emerged as the leading growth market for wind power and has surpassed all other markets in terms of total cumulative size. By the end of 2012, the cumulative installed capacity of wind power reached 75.564 GW, representing a share of 26.75% in the world total, while the cumulative capacity of its solar PV power was only 6.8 GW, accounting for 6.80% in the world total, lagging far behind its wind power market (Fig. 3) [4]. Nonetheless, China's solar PV power manufacturing industry has developed alongside with its wind power manufacturing industry. Indeed, both industries have developed dramatically in only a few years' time and have taken the leading positions in the world.

The research questions in this paper are: What are the similarities and differences between the development trajectories of wind power and solar PV power in China? What findings can be obtained and policy recommendations can be made from this comparison? The remainder of the paper is organized as follows: Sections 2 and 3 examine the development status and policy of

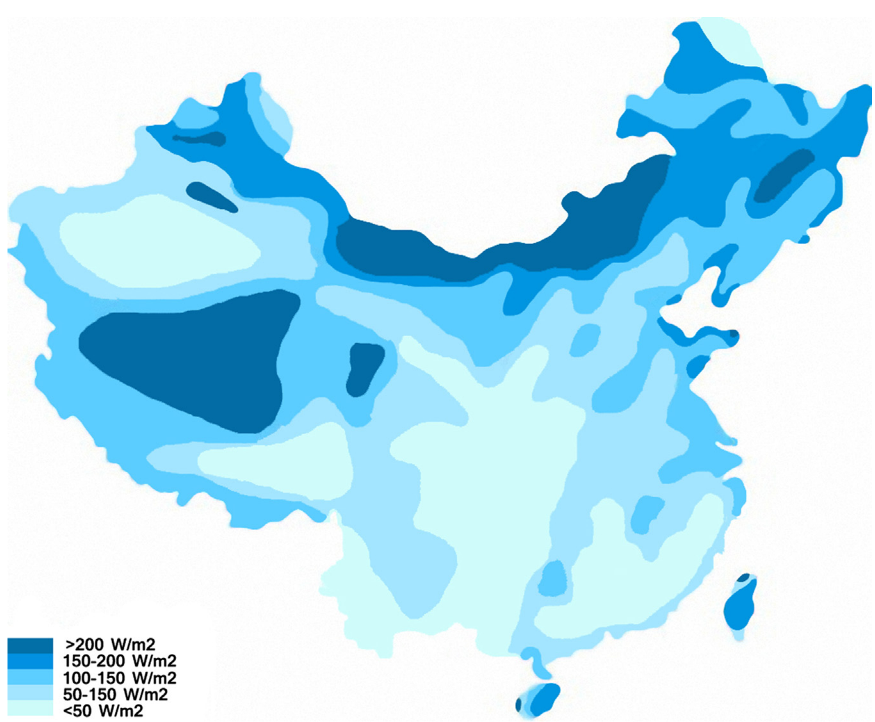


Fig. 1. Distribution of wind resources in China.
Source: [2].

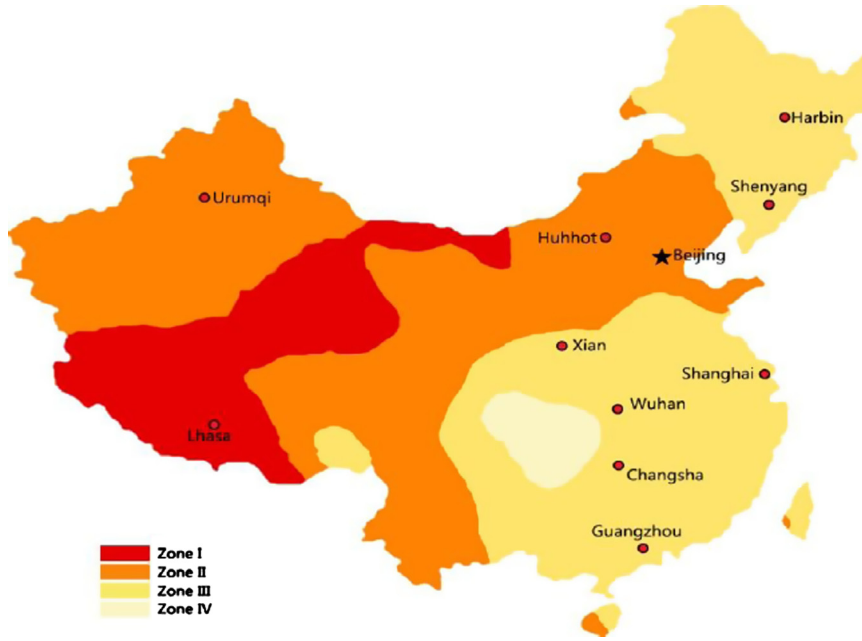


Fig. 2. Distribution of solar resources in China.
Source: [3].

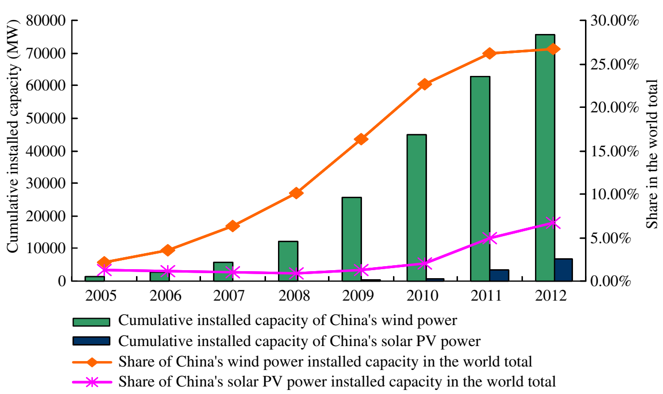


Fig. 3. Comparison of cumulative installed capacity of wind power and. solar PV power in China (2006–2012) *Source*: Author's calculation based on data from [4–7].

China's wind power and solar PV power, respectively, which is followed by a comparison of the development trend of the two renewable technologies in Section 4. Concluding remarks and policy recommendations are provided in Section 5. This paper contributes to the study on China's renewable energy from a new perspective.

2. Development status of wind and solar PV power in China

In this section, we take a look at the current development status of both market and manufacturing industry development of wind and solar PV power in China. A brief comparison is made at the end of the section.

2.1. Development status of wind power in China

Since the year 2005, wind power capacity in China has seen an unprecedented growth. In terms of cumulative installed capacity, China has ranked the first in the world for three consecutive years since 2010 when it surpassed the USA for the first time [4,5]. In 2012, China's cumulative installed capacity reached 75.56 GW, representing 26.75% of the world total (Fig. 4) [4]. The strong growth of China's wind power capacity in recent years has consistently surpassed even the most optimistic expectations of industry observers.

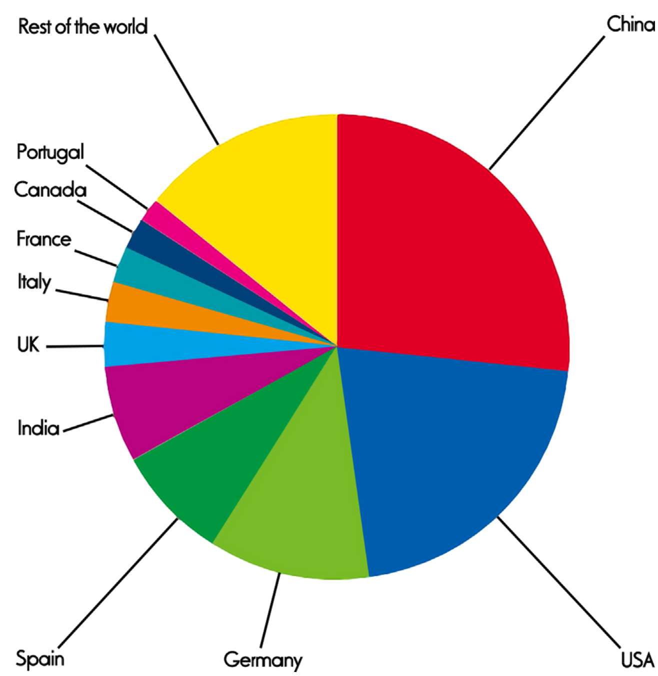


Fig. 4. Market shares of top 10 wind turbine in the world in 2012.
Source: [4].

The enormous expansion of China's domestic wind power market has been accompanied by the rapid growth of Chinese domestic manufacturing industry. A decade ago, domestic manufacturers of wind power equipment hardly existed in China. At the end of 2000, there were a total of about 10 wind turbine manufacturers in China, together holding a domestic market share of less than 10%. Until 2005, more than 70% of the wind power equipment was imported [9].

However, in reaction to the explosive growth of the domestic wind power market, a whole field of domestic producers has appeared. In 2011, there were more than 70 domestic wind turbine manufacturers. Four Chinese companies, Goldwind, Sinovel, United Power and Mingyang saw strong growth and were among the world Top 10 wind turbine manufacturers (Fig. 5), together representing 26.7% of the world total [8].

As in the rest of the world, expansion in the production volume was accompanied by a steady increase of technological capacities. At the end of 2006, only one-tenth of all installed turbines in China were larger than 1 MW. The domestic turbines had a rather simple design and were less efficient than larger and more advanced Western turbine models. Yet today the large wind turbine companies in China are able to produce not only 1.5 MW, 2 MW and 3 MW wind turbines, but also 5 MW wind turbines and offshore wind turbines. The average scale of wind turbines has also increased from 849.7 kW in 2005 to 1545.4 kW in 2011 (Fig. 6). Domestic companies can produce all the important components of a wind power system [5].

It is obvious that local demand scale has played a fundamental role in driving the development of China's wind turbine manufacturing industry. However, as pointed out by Michael Porter,

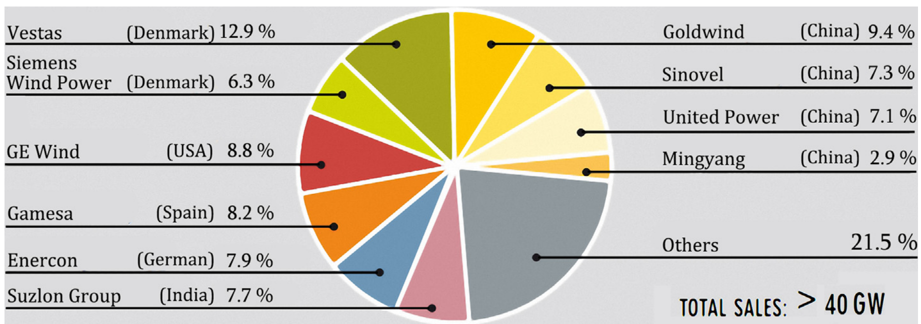


Fig. 5. Market shares of top 10 wind turbine manufacturers in the world. in 2011.
Source: [8].

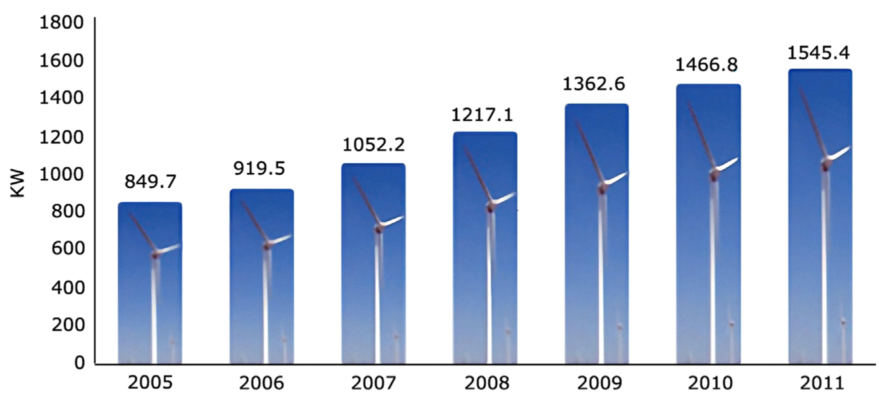


Fig. 6. The average scale of wind turbines in China: 2005–2011.
Source: [5].

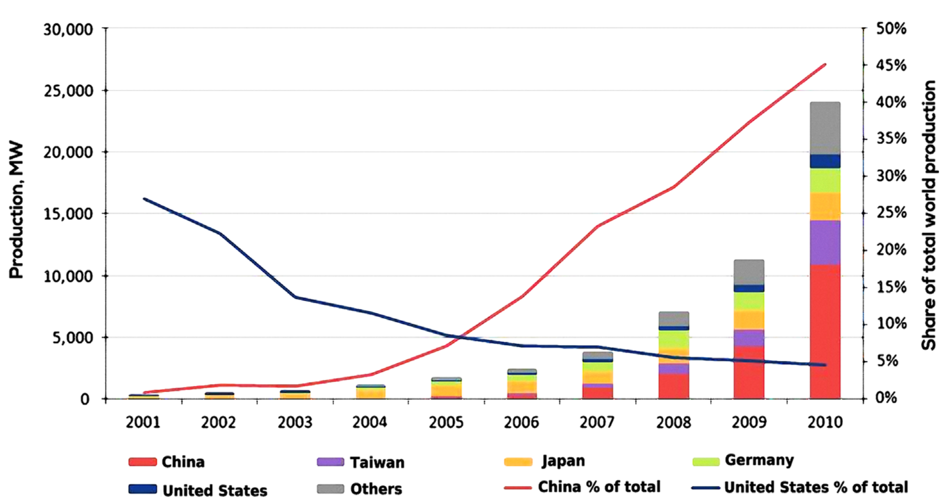


Fig. 7. Global solar PV production by country: 2001–2010.
Source: [12].

local market scale is like a double-edged sword. On the one hand, it helps to foster industrial international competitiveness as it stimulates investment; on the other hand, huge local opportunities may prevent local companies to expand abroad. Indeed, China's overseas operation has been weak. It was not until 2009 that China started to export complete wind turbines to four countries, namely the USA, Thailand, Britain and India, with a total of 20 sets with an aggregate capacity of 28.75 MW. In 2010, China only exported 13 sets of complete wind turbines, with a total capacity of 15.55 MW to countries such as Cuba, the United States, Chile, Belarus and Thailand [10].

2.2. Development status of solar PV power in China

China's solar PV market growth has been restricted by the high cost of solar PV system. For many years, China's PV power market had centered on off-grid rural electrification projects, which only allowed for a very small number of installations. However, installed capacity of solar PV in the country hit a record high of 3.3 GW in 2011and another record high of 3.5 GW in 2012, bringing the country's cumulative installed capacity to 3.3 GW and 6.8 GW, representing 4.95% of 6.7% of the world total in 2011 and 2012, respectively. These achievements were assisted by the decreasing cost of the PV system and by the government's incentive policies for the China's domestic market since 2009 that aimed to help the domestic solar PV industry which had been hit by the shrinking demand from European countries due to the world financial crisis in 2008 [6,8,11].

China did not play a significant role in solar PV manufacturing until a decade ago. However, since global PV deployment started taking off in 2004, China has been the most successful in capturing an increasing large share of this rapidly growing market. In the course of just a decade's time, its market share of solar PV production grew from about 1% in 2001 to around 45% of the world total in 2010 [12] (Fig. 7).

In 2011, the production of polysilicon in China amounted to 84,000 M/T [13], ranking the first in the world. During the 11th Five Year Plan (FYP) period (2006–2011), the production of solar cells developed at an annual growth rate of more than 100% and ranked the first in the world for five consecutive years with China's crystalline silicon cells accounted for more than 95% of total solar cell production [14]. In 2011, China manufactured 21 GW of solar cells, representing 60% of the global total production, to secure its leading position [14]. Out of the top fifteen solar PV module manufacturers in the world, nine were Chinese companies which took a share of 30% in the world (Fig. 8) [14].

Along with the increasing output, China's solar PV production technology and the quality of solar cell have improved year by year. In particular, leading enterprises have made rapid progress in terms of conversion efficiency. At present, the conversion rates for monocrystalline silicon solar cells, polycrystalline silicon solar cells and thin-film and other new types of cells have reached 17–19%, 15–17% and 6–8%, respectively [14].

Another important feature of China's solar PV manufacturing industry is its heavy reliance on world market. Due to its small domestic market and the large overseas demand stimulated by market incentives, for example in Europe, particularly Germany, China exports 90% of its PV products. The export value of solar cells in 2011 reached USD 22.67 billion, a share of 60% of the global market [14].

2.3. Summary

The development status of China's wind power and solar PV power shows that China's wind power market has been taking the leading position in the world in terms of installed capacity in only a few years while its domestic market for solar PV products has to date been puny, but has begun and should continue to increase quite dramatically, potentially eating up a lot of the production capacity in China. Over the past years, China's wind and solar power manufacturing industry have both experienced rapid growth and have taken the leading position in the world. These development features demonstrate that the development trajectories of wind and solar PV industry differ in that wind turbine industry largely relies on domestic market while solar PV industry largely relies on overseas market.

3. Wind and solar PV power policy in China

The different development trajectories of China's wind and solar PV power lie in the government's policies. Thus, in this section, we seek to find out how the policies have impacted the development trajectories of these two sectors. We first examine the *Renewable Energy Law* (*the law*) which supports all renewable technologies, and then the specific policies for wind power and solar PV power sector are analyzed.

3.1. The Renewable Energy Law

China began to enact its *Renewable Energy Law* on January 1, 2006. The law created for the first time a national framework for promoting renewable energy development in the country by establishing five important mechanisms: (1) Setting national targets for the development of renewable energy; (2) Mandatory access to grid which requires grid companies to purchase all renewable generation and provide grid connection services; (3) Classifying tariffs for renewable energy electricity. Separate pricing laws are applied for each type of renewable energy; (4) Cost sharing arrangements which require the cost of renewable energy generation and grid connection be shared by all power users

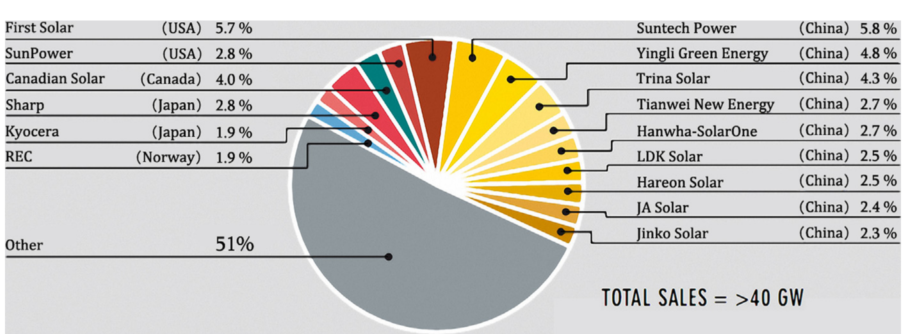


Fig. 8. Market shares of top 15 solar PV module manufacturers in 2011.
Source: [8].

through imposing an additional tariff; (5) Establishing special fund which offers additional financial support such as subsidies and grants to renewable energy players in their production and technological innovation, among others [15].

Pursuant to the promulgation of the *law*, a series of regulations and plans were issued to implement the law, one of which is the *Medium- and Long-term Renewable Energy Development Plan* promulgated by the *National Development and Reform Commission* (*NDRC*) in 2007. The Plan established a "Mandatory Market Share" (MMS) requirement for grid companies and generators for non-hydro renewable power. The grid companies were to achieve 1% of their total power generation from non-hydro renewable power by 2010 and 3% by 2020, and investors (i.e. generators) with authority to install over 5 GW of power capacity were required to achieve 3% of their total installed capacity from non-hydro renewable power by 2010, and 8% by 2020 [16]. Since wind power is the most mature renewable energy technology with the lowest cost, generators would prefer to invest in wind power to meet this requirement, which has an obvious negative impact on the development of solar PV power market in China.

3.2. Wind power policy in China

China's policies specifically support the development of wind power development include the wind concession program, nationwide Feed-in-Tariff (FIT)scheme, and financial incentives and the R&D support for domestic industry, among others.

3.2.1. The wind concession program

The wind concession program initiated in China in 2003 has two main objectives: (1) promoting the manufacturing capacity of domestic wind turbines and component industry, and (2) lowering costs by enhancing price competition. Additional program objectives include promoting the technology transfer of advanced wind energy technology, and gaining insight in what prices would be reasonable for wind farm development, which played a role in determining China's later FIT.

Under this program, the government ensured the purchase of all electricity generated by the bidder's wind farms and the grid company was mandated to construct the power transmission lines required for connecting the concession wind farms to the nearest network. This stimulated great enthusiasm for wind farm investment. The installed capacity during the five rounds of concession amounted to 2600 MW, 48.1% of the nation's total [16].

In addition, the concession program had local content requirements. The requirements began with mandating 50% local content in 2003, and increased to 70% in 2004 [17]. The result of this was clearly noticeable with China now having four wind power manufacturers that are competing with the world's top ten.

3.2.2. The nationwide FIT scheme for wind power

Prior to August 2009, there are two alternative pricing modes for wind power. For wind concession projects, prices were based on a bidding process. Whereas pricing for other projects were based on a benchmark determined by the unit price for local coal-powered electricity generation. In cases where wind power project costs were higher than this benchmark, the regulation made it possible to cover part of the costs with revenues from an "additional renewable energy tariff" levied on all sales of electricity. Initially, the bidder who agreed to build a wind farm with the lowest bidding price would win the bid. This was later revised so that the electricity price was given 40% of the total weight in deciding the winning bids.

In August 2009, China began to implement a nationwide four-category FIT scheme for new onshore wind power projects. The regions with the richest wind resources in the north, northeast and northwest region have been given a tariff of CNY 0.51 per kW h, CNY 0.54 per kW h and CNY 0.58 per kW h, respectively; and the region with relatively less wind resources, central China, was given a tariff of CNY 0.61 per kW h. This FIT scheme represented a significant premium for wind power generation over coal-fired electricity generators and has further stimulated developers' interests in wind farm investment.

3.2.3. The financial incentives for wind power

The Chinese government also provides a variety of financial incentives to promote the development of wind power. These incentives come in the form of tax reduction or exemption. The VAT rate has been reduced from a normal rate of 17% to 8.5%, and the income tax rate of wind power projects from a normal rate of 33% to 15% [9]. In 2008, the Ministry of Finance (MOF) granted VAT and import duties rebates to Chinese wind turbine manufacturers on all imported wind-turbine components and materials. Meanwhile, for the purpose of encouraging wind farm developers to adopt the higher-capacity machines of 3 MW or more from foreign manufacturers, the tariff-free policy on the import of wind-turbines with a capacity of less than 2.5 MW was cancelled in a bid to bolster the sales of domestic wind turbine industry [18]. The noticeable result of this is that the ability of China's domestic wind industry in manufacturing larger turbines has evolved quickly.

3.2.4. The R&D support for domestic industry

In August 2008, the MOF issued *The Management of Special Fund for Wind Power Manufacturing Sector*, which specifies the establishment of a special fund in support of domestic research and development of MW-scale wind turbine systems. Wind power equipment manufacturers fulfilling the fund's qualifications will be eligible for a CNY 600 per kW grant for the first 50 wind turbines produced [19].

3.3. Solar PV power policy in China

The major solar PV policies in China include the Brightness Program (1996), the Township Electrification Program (2002), the Solar Rooftop Program (2009), the Golden Sun Demonstration Program (2009), the Solar PV Concession Program (2009) and the Nationwide FIT scheme (2011), among others.

3.3.1. The Brightness Program and Township Electrification Program

In 1996, China implemented the Brightness Program, the aim of which was to use PV modules and wind power systems to provide power for daily needs to the population of 23 million in China without access to electricity. In 2002, another similar program—the *Township Electrification Program* was initiated to meet the power needs of un-electrified rural areas in Western China. These two programs were the major driving force for solar PV market expansion in China in the late 1990s and early 2000s.

3.3.2. The Solar Roofs Program and Golden Sun Demonstration Program

In March 2009, the Solar Roofs Program which provides upfront subsidy of CNY 15/W for rooftop systems and CNY 20/W for building integrated PV systems, was initiated [20]. In July 2009, another solar subsidy program—the Golden Sun Demonstration Program which provides 50% of the total cost for on-grid systems and 70% of the total cost for off-grid systems was implemented [21].

As of 2012, both programs have gone through four phases. The approved capacity of solar building projects under the two programs totals 551.2 MW. These two subsidy programs clearly

demonstrate China's determination to stimulate the solar PV market in the country [22].

3.3.3. The solar PV concession program

In March 2009, China organized the first public bidding for the 10 MW solar PV project in Gansu Province, and then approved a FIT at CNY 1.09 per kW h. In June 2010, a second round of public tender for solar power concession projects was initiated. At the end of this tender, 13 projects with an aggregate capacity of 280 MW were announced. While the successful bidders were required to complete the construction in 24 months, they would have an exclusive right to operate the plant for 25 years with a FIT [3].

Consequently, nationwide enthusiasm for solar PV was stimulated and there was a surge in China's solar PV market. China's solar PV electricity price has been significantly reduced from CNY 4 per kW h in 2008 to CNY 1 per kW h or less in 2010. Nonetheless, at this stage the burgeoning solar PV market was only considered an experimental phase by the Chinese government, and projects were just for demonstration purposes.

3.3.4. The nationwide FIT scheme for solar PV power

As the bid prices of the projects under the concession program were much lower than some solar industry participants had expected, energy power companies and private solar equipment suppliers were discouraged from investing in China's solar market. It is against this background that in July 2011, China announced its first nationwide FIT scheme for solar PV development in an effort to boost China's domestic solar industry and to increase the share of solar power in China's energy portfolio.

The FIT scheme provides that: (1) Projects approved prior to July 1, 2011, which have completed construction and have achieved commercial operation prior to December 31, 2011, are entitled to a tariff of CNY 1.15 per kW h; (2) Projects approved after July 1, 2011 or approved prior to that date but cannot be completed before the end of 2011 are entitled to a tariff of CNY 1 per kW h. And exceptions have been given to projects located in Tibet, which, under certain circumstances can still receive a FIT of CNY 1.15 per kW h [23].

In addition to the support from the central government, financial support is also from provincial and local governments who offer low-interest loans and land at reduced cost aimed largely at pulling local GDP and employment growth.

3.4. Summary

It appears that China's wind power sector has particularly profited from the favorable market conditions the Renewable Energy Law helped to establish. As the most competitive of renewable energies in terms of costs, maturity of technology and feasibility of large-scale deployment, wind energy is the premier renewable energy technology benefiting from the government targets. In contrast, China's solar PV power which is less cost-competitive has benefited less from the law and relevant policies. It was not until 2009 when the government rolled out measures to boost its domestic solar market for the purpose of weaning the country's solar PV industry off dependence on overseas market that solar PV power market in the country started to grow rapidly.

There is one similarity between the policies in the two sectors, that is, to a large extent, these policies are “growth imperative” incentives for industry rather than “green imperative” incentives for renewable power output. Wind power policies such as concession programs and financial support policies have mainly aimed at the promotion of domestic manufacturing capacity of wind turbines and component industry. This is more obvious in the case of solar PV power. Prior to 2009, few incentives have been put in place to stimulate domestic solar PV market. Incentives such as low-interest loans and land at reduced cost provided by local governments have largely targeted at enhancing GDP and employment. Indeed, these policies appear to have been successful in assisting Chinese wind and solar PV power manufacturers to rapidly expand over a short period of time [24].

4. Development trend of wind and solar PV power in China

Faced with similar increasingly intense domestic competition, wind and solar PV power manufacturing industries in China display similar development trends, including a trend of consolidation and vertical integration, a trend of diverse pattern development and a trend of market transition.

4.1. Trend of consolidation and vertical integration

Along with the dramatic development of wind turbine and solar PV manufacturing industry, market competition is growing increasingly fierce in China. Wind turbine and solar PV producers have to look for new strategies to ensure profitability and preserve gross margins. Consolidation and vertical integration (upstream integration and downstream integration) in the industry is one of the new strategies.

4.1.1. Consolidation and vertical integration in wind power

China's wind manufacturing industry is witnessing intense competition, which arises mainly from three factors: (1) Grid integration constraints. Despite the rapid growth of installed wind power capacity in the past seven years, grid-connected capacity of wind power has lagged behind installed capacity by more than 30%, greatly restraining the manufacturing capacity in this sector; (2) Stricter quality requirements. As wind power capacity has grown, so has the number of wind turbine disconnection incidents and wind turbine breakdown incidents in recent years. As a result, the government has stepped in to address quality problems and to prevent the market from overheating. New standards and certification requirements have been issued, while project approval has become stricter; (3) More and more entrants. As companies expanded and the industry attracted new entrants prepared to offer low prices in return for initial sales, the price of wind turbine has plummeted by more than 40% since 2008, from CNY 6500 per kW in 2008 to CNY 3700 per kW in 2011 [5]. Intense competition has led to consolidation and vertical integration in the industry.

(1) Consolidation. Prior to 2005, China had only a few small scale and low tech domestic wind power equipment manufacturers, which constituted a relatively fragmented portion of the landscape. As a result of the localization content requirements, local manufacturers of wind power facilities proliferated. At present, low-end wind power market in the country is becoming saturated, and the industry is entering an era of consolidation. Industry experts forecast that 80% of the manufacturers are likely to be out of the market in two to three years [25].

(2) Vertical integration. China's wind power equipment manufacturers have begun to strengthen their vertical integration along the industry chain to guard against changes in their business environment. The largest Chinese manufacturers are pursuing either upstream or downstream integration along the value chain. Goldwind is the first to implement vertical integration and has some successful wind farm projects. In recent years, other companies such as HeWind, Tianwei Group, and XEMC Wind power, among others, have also developed their wind farm projects. On the other hand, Chinese wind turbine companies such as Goldwind, Sinovel, the United Power, Mingyang and Sanyi have started

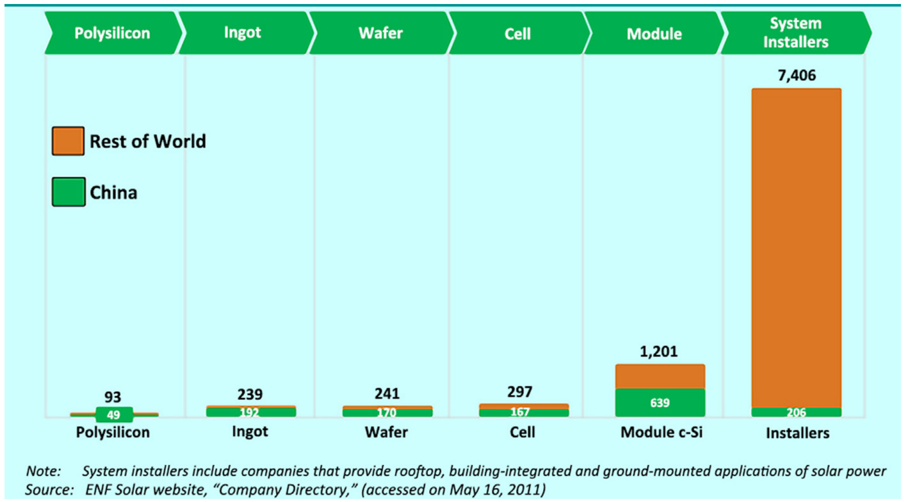


Fig. 9. Global and Chinese solar PV producers.
Source: [11].

to produce components for their own use by taking advantages of their R&D, with production mostly concentrate on blades, generators, inverters and control systems.

4.1.2. Consolidation and vertical integration in solar PV power sector

Similar to the wind power sector, consolidation and vertical integration are also taking place in China's solar PV power sector because of fierce competition due to the demand slump in major foreign markets and trade frictions with the U.S.A. and Europe.

(1) Consolidation. Due to local government support for solar PV industry, hundreds of Chinese companies have entered the market. Most of these companies are in the module manufacturing segment, due to the relative ease of market entry compared to the more capital- or technology-intensive polysilicon and solar cell segments of the value chain. Turn-key manufacturing lines can be purchased, installed and rapidly put into production and as a result, there are over 600 module producers in China compared to 167 cell companies and fewer than 50 polysilicon producers [11] (Fig. 9).
While hundreds of module companies exist in China today, most production is concentrated in the factories of only a few top-tier producers. The top five module companies in China accounted for over 60% of production capacity. Given the high number of China's independent companies in downstream module and project development, many analysts expect to see the initiation of industry consolidation.

(2) Vertical integration. In 2010, China imported 50% of its polysilicon, and much of its domestic supply came from small, low-quality producers. Given the constraints in China, many Chinese companies such as Yingli and LDK have been developing in-house capacity. Yingli began in the module segment of the value chain and has gradually expanded into polysilicon production. LDK, on the other hand, started out in wafer production and then simultaneously integrated upstream into polysilicon and downstream into cells and modules. Trina Solar now manufactures its own ingots, wafers, cells and modules and installs its own projects.

While many solar companies in the U.S. and Europe have long been active in project development – Sunpower and Solar World, for example – Chinese solar companies have focused on manufacturing modules and other components. With many markets across the world growing rapidly, companies look to project development and operation and maintenance (O&M) services as promising new revenue streams, as well as a path to secure demand for their own modules in new markets [14].

4.2. Trend of diverse development pattern

4.2.1. Diverse pattern of wind power development

Prior to 2010, China's wind power policies had emphasized the establishment of large bases for incorporation into the main grid. Along with the dramatic growth of installed capacity, however, grid-connection problems pose a major challenge for the sustainable development of wind power in the country. Ineffective dispatch is bound to hinder the construction and expansion of wind farms, thereby inhibiting the demand for wind power equipment and undermining the industry's sustainability.

As such, the government has sought to address the problem by giving support to less resource-rich regions in China, such as Yunnan, Anhui, Hubei and Hunan. This could promote the decentralized development of low-speed wind farms. The objective is for the installed capacity of wind power in low-wind-velocity regions to reach 20% of total installed wind power and distributed development will be encouraged.

4.2.2. Diverse pattern of solar PV power development

China has drawn lessons from its wind power sector for the development of its solar PV projects. The regulators have become aware that concentrated solar PV power projects should not be encouraged in the near future as it would bring about challenges to grid connection and grid stability. Therefore, the strategy China has decided to take is to promote a diverse pattern of solar PV power development by integrating intensive exploitation with distributed utilization. In addition to large on-grid photovoltaic power stations and solar power generation projects in solar energy abundant western regions, it will also encourage the central and eastern regions to construct distributed photovoltaic power generation systems linked to local buildings.

Targets for both the installed capacity of distributed power generation and large power stations during the 12th Five-Year Plan period (2011–2015) have been set at 10 GW. This implies that distributed solar PV power generation should be regarded as an important part of China's future solar PV market application.

In addition, the government will seek to establish an administration mechanism where distributed solar PV power generation network for private use can be connected with power grid indiscriminately and conveniently [14].

4.3. Trend of market transition

Both wind and solar PV industry are seeing market transition, due to the change of development environment. It is, however, interesting to note that their market transitions are in opposing directions: while the wind power sector is transitioning to a global market, the solar PV power sector is transiting to domestic market.

4.3.1. Wind power industry: Transitioning to global market

The fierce competition in domestic wind market is a strong incentive for Chinese manufacturers to seek overseas exports in order to survive. More exports are coming up and a growing number of Chinese wind turbine firms, such as Sinovel, Goldwind and Dongfang, have signed deals with the USA, Greece, Brazil, Canada and South Africa for exporting turbines. In 2011, the Chinese firms ramped up their overseas activities. According to the information released by the companies themselves, Sinovel acquired an order for wind turbines from Brazil. The United Power, the Sany Group and the CSIC (Chongqing) Haizhuang Wind Power Equipment Co. acquired orders from the United States, Shanghai Electric acquired an order for 125 wind turbines from India, and Goldwind has achievements in the United States, Australia, Chile, Ecuador, Ethiopia [5].

In addition, the China Development Bank and companies such as Hydrochina International Engineering Corporation, China Datang Corporation, and China Energy Conservation Corporation have also been exploring overseas wind farm construction projects, which would be conducive to the exports of Chinese wind turbines. Furthermore, the Chinese test and certification agency, China General Certification Center (CGC), has been making great efforts to push forward the international recognition of Chinese certification of wind equipment, which to some extent, will eliminate the trade barriers facing China's wind equipment [5].

4.3.2. Solar PV industry: Transitioning to domestic market

As previously noted, China's growth of solar PV industry has greatly relied on overseas markets. However, due to the impact of world economic and financing crisis on renewable energy support schemes in some countries, especially European countries which are by far the largest market for China's solar PV products, exports of the Chinese solar PV industry have been greatly affected. It was in this context that the Chinese government recognized the need to support this critical growth industry with domestic demand to reduce dependency on overseas markets. Ever since March 2009, particularly during 2011–2012, a series of incentives have been implemented by the government. In response to these incentives, China's domestic PV market has seen a dramatic growth over the past two years.

5. Comparison findings and policy recommendations

5.1. Comparison findings

Table 1 summarizes the comparison of China's wind and solar PV power development status, policies and trends discussed above.

Five interesting findings are obtained through the comparison: (1) Both the wind power and solar PV power sectors in China are taking the world leading position in terms of manufacturing capacity, but China's solar PV power market lags far behind its wind power market; (2) The “growth imperative” incentives appear to have been successful in assisting Chinese wind and solar PV power manufacturers to rapidly expand over a short period of time; (3) Owing to its competitive advantage in costs, maturity of technology and feasibility of large-scale deployment, wind power has particularly profited from the favorable market conditions that China's Renewable Energy Law helped to

Table 1
Comparison summary of wind and solar PV power development in China.

		Wind power	Solar PV power
Development status	Market	Dramatic growth since 2005; Leading position in the world	Rapid growth since 2010
	Industry	Dramatic growth since 2005; Leading position in the world; Rely on domestic market	Dramatic growth since 2004 Leading position in the world Rely on overseas market
Development policy	Renewable Energy Law	National targets for renewable energy; Mandatory access to grid; Classifying FIT; Cost sharing; Special fund	National targets for renewable energy Mandatory access to grid; Classifying FIT Cost sharing Special fund
	Concession program	Started in 2003; Five rounds implemented; Localization requirement	Started in 2009 Two rounds implemented
	Nationwide FIT	Established in August 2009, land-based, four categories ranging between CNY 0.51per kW h and CNY 0.61 per kW h. Areas with the least abundant wind resources receive the highest tariff and areas with the most abundant resources receive the lowest tariff	Established in July 2011, CNY 1.15 per kW h for all solar PV projects approved before July 1, 2011 and completed by Dec. 31, 2011, and CNY 1.00 per kW h for projects approved after July 1, 2011 or not completed by Dec.31, 2011. Tibet has a FIT of CNY 1.15 per kW h for all projects
	Financial support	Tax reduction or exemption for wind farm projects and wind turbine producers	Upfront subsidy for solar PV projects Low-interest loans and land at reduced cost
Development trend	Consolidation & vertical integration	Yes	Yes
	Diverse pattern	Yes	Yes
	Market transition	Transitioning to global market	Transitioning to domestic market

Note: Only items that are related to both wind power and solar PV power are compared.

establish; (4) The development of China's wind power has provided and will provide valuable lessons and experience for its solar PV power; (5) Both sectors are entering a new phase and policy adjustments should be made.

5.2. Policy recommendations

In light of the above findings, we make the following policy recommendations:

5.2.1. Expedite the establishment of renewable energy quota system

As previously noted, wind power has been preferred by investors who have proportion commitments within mandatory timelines set by the MMS. As a consequence, less investment has gone to solar PV power. Renewable energy quota system has been discussed in China for nearly one decade. In Feb. 2012, the State Energy Bureau issued the *Management Methods on Renewable Energy Quota* (*Draft*). However, to date the quota system has not been put in place mainly due to objections from local governments and grid companies. It is recommended that China expedite the establishment of the renewable energy quota system, under which a diverse renewable energy portfolio would be encouraged so as to utilize renewable resources in a coordinated way.

5.2.2. Construct sophisticated nationwide FIT schemes

The current four-category nationwide FIT scheme for wind power only takes into account differences in available wind resources. Given the severe grid-connection and curtailment problems with wind power, it is recommended that not only the wind resources but also grid-connection conditions be considered in the determination of FIT level. In the case of solar PV power, the current FIT scheme is a uniform tariff, thus the areas with rich solar resources have been more preferred by project developers. Therefore, there is a likelihood that the problem of solar PV power congestion or curtailment will occur. It is therefore recommended that a differentiated FIT scheme based on regional resources difference be constructed for solar PV power, as in the case of wind power.

5.2.3. Draw up internationalization strategy for wind power industry

China's wind power manufacturing industry gained its start in its home country market. Now that the industry is transitioning and competing in the international market, Chinese wind power companies must overcome multiple challenges before securing a strong position in the overseas marketplace. These challenges include competition with well-established local players in Europe and the US, requirements for certification regarding proprietary intellectual property rights, quality and stability of the products, and financing needs of upstream and downstream enterprises. To surmount such obstacles, these domestic players will need to build their International operation capacity and set up global operations. The strategy of exploring overseas mergers and acquisitions (M&A) may be adopted as it stands as the most direct and expeditious way to build up competitiveness. Such M&A can give Chinese companies rapid access to advanced technology, talent, well-established brands and international management teams [25].

5.2.4. Setting technical standards for the grid-connection of solar PV systems

It is expected the domestic solar PV market will be expanding rapidly with the growing number of incentive policies from the government. However, higher penetration of solar PV power would greatly impact the security and stability of power grid system. As such, it is crucial to establish state-level technical rules standards for the grid-connection of solar PV projects. In this respect, lessons from wind power development could be drawn by the government.

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References

[1] Chunchun Ni. China's wind-power generation policy and market development. International Electrical Engineering Journal 2008.
[2] Liu Wen, Lund Henrik, et al. Potential of renewable energy systems in China. Applied Energy 2011;88:518–25.
[3] Zhang Sufang, He Yongxiu. Analysis on the development and policy of solar PV power in China. Renewable and Sustainable Energy Review 2013;21: 393–401.
[4] Global Wind Energy Council (GWEC), 2013. Global wind statistics 2012.
[5] Li Junfeng et al. China wind power outlook 2012. ⟨http://www.gwec.net/wp-content/uploads/2012/11/China-Outlook-2012-EN.pdf⟩.
[6] Steadman Ian. 2013. Wind and solar saw record growth in 2012, industries claim. ⟨http://www.wired.co.uk/news/archive/2013-02/12/world-solar-capacity-101gw⟩.
[7] Global Wind Energy Council (GWEC), 2012. Global wind statistics 2011.
[8] REN 21, 2012. Renewables 2011 Global status report.
[9] Kang JJ, Yuan JH, et al. Review on wind power development and relevant policies in China during the 11th Five-Year-Plan period. Renewable and Sustainable Energy Reviews 2012;16:1907–15.
[10] Zhang Sufang. International competitiveness of China's wind turbine manufacturing industry and implications for future development. Renewable and Sustainable Energy Reviews 2012;16:3902–9.
[11] REN 21. Renewables 2012 global status report.
[12] ChinaGlobalTrade.com. China's solar industry and the U.S. anti-dumping/anti-subsidy trade case; May 2012 ⟨http://www.chinaglobaltrade.com/sites/default/files/china-global-trade-solar-manufacturing_may2012_0.pdf⟩.
[13] Xu Honghua, Charlie Dou, et al. National survey report on PV power application in China; 2011, ⟨http://www.iea-pvps.org/⟩.
[14] 12th five-year plan for the solar photovoltaic industry, ⟨http://www.americansolarmanufacturing.org/news-releases/chinas-five-year-plan-for-solar-translation.pdf⟩.
[15] National People's Congress of China. The renewable energy law of the People's Republic of China; Feb. 2005. ⟨http://www.martinot.info/China_RE_Law_B⟩.
[16] National Development and Reform Commission (NDRC). Medium- and Long-term Renewable Energy Development Plan; 2007. ⟨http://www.cwpc.cn/cwpc/zh-cn/node/25⟩.
[17] Lewis Joanna I, Wiser H Ryan. Fostering a renewable energy technology industry: an international comparison of wind industry policy support mechanisms. Energy Policy 2007;35:1844–57.
[18] Ma Jinlong. On-grid electricity tariffs in China: development, reform and prospects. Energy Policy 2011;39:2633–45.
[19] Ministry of Finance (MOF). The management regulations on special fund for wind power manufacturing sector in China; July 2008.
[20] Ministry of Finance. Interim management method for financial subsidy fund for building integrated PV systems; March 2009.
[21] Ministry of Finance, Ministry of Science and Technology, State Energy Bureau. Interim management method for financial assistance fund supporting golden sun demonstration programs; July 2009.
[22] Lv Fang Perspectives for a post-FIT regulatory framework in China. PVPS T14. In: Fifth Expert Meeting: Workshop. Sep. 27; 2012. ⟨http://iea-pvps.org/index.php?id=15&no_cache=1&tx_damfrontend_pi1[pointer]=2⟩.
[23] Wigmore Gary S, Liu Shepard, et al. China: China policy: Shedding light on the recently enacted solar feed-in-tariff. ⟨http://www.mondaq.com/x/159390/Renewables/China+Policy+Shedding+Light+On+The+Recently+Enacted+Solar+FeedInTariff⟩ 04 January 2012.
[24] Philip Andrews-Speed. The governance of energy in China: Transition to a low-carbon economy. Palgrave Macmillan, Basingstoke; 2012.
[25] Yang Claire, Qian Wei, et al. China's wind-power industry: the insider's view; May 2012. ⟨http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-China-Wind-Power-Industry.pdf⟩.